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# Active Interrogation of SNM with NRF

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# Active Interrogation of SNM with NRF



Micah S Johnson

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# Outline

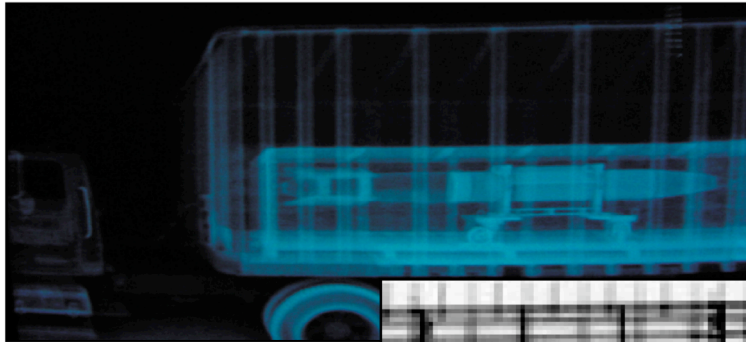
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- Motivation for isotopic mapping - NRF scanning
- Background
- NRF scanning technology in development at LLNL
- Measurements of Pu
- Summary and future work

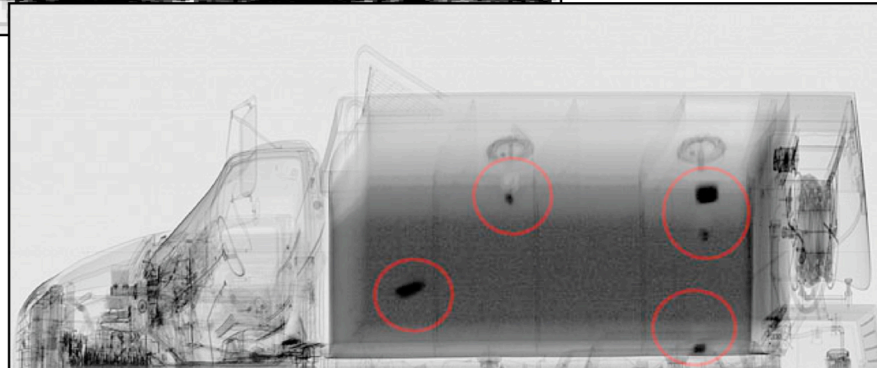


# Current systems: radiography

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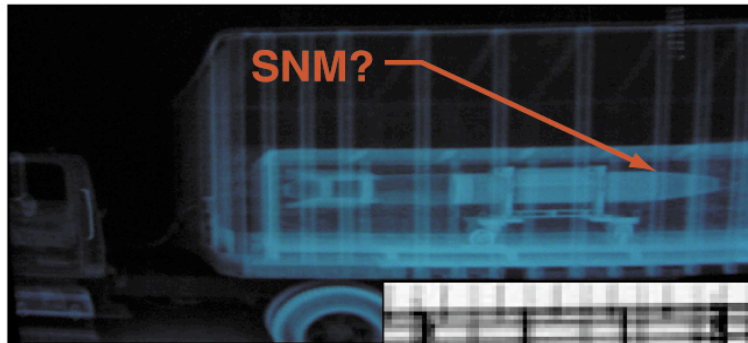


Visually powerful, but is far from perfect for SNM detection

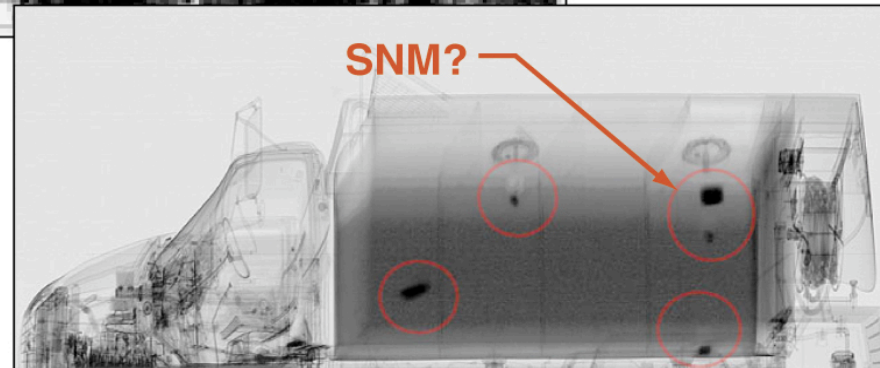
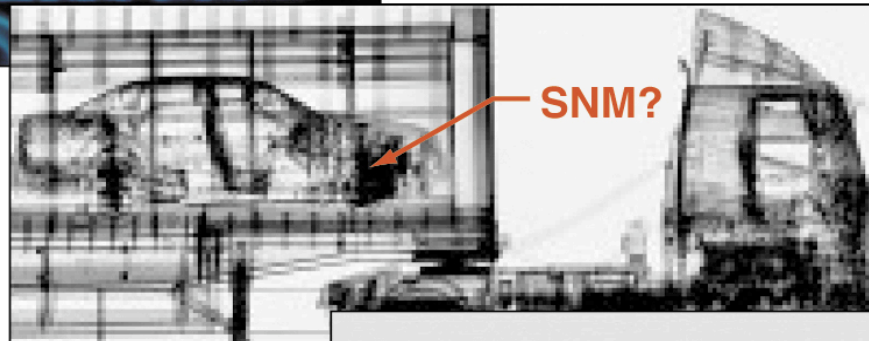


# Limitation: density silhouette

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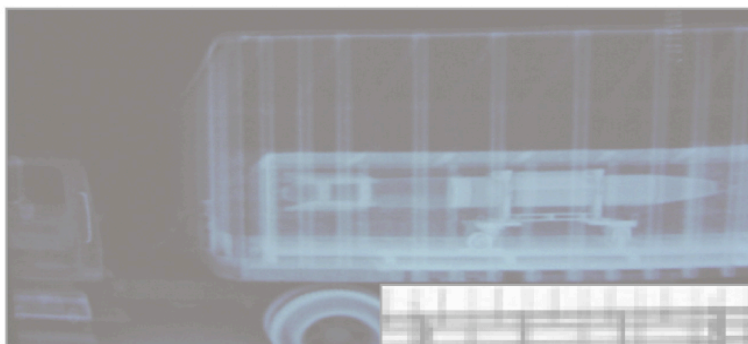


Visually powerful, but is far from perfect for SNM detection



# NRF $\Rightarrow$ isotopic sensitivity

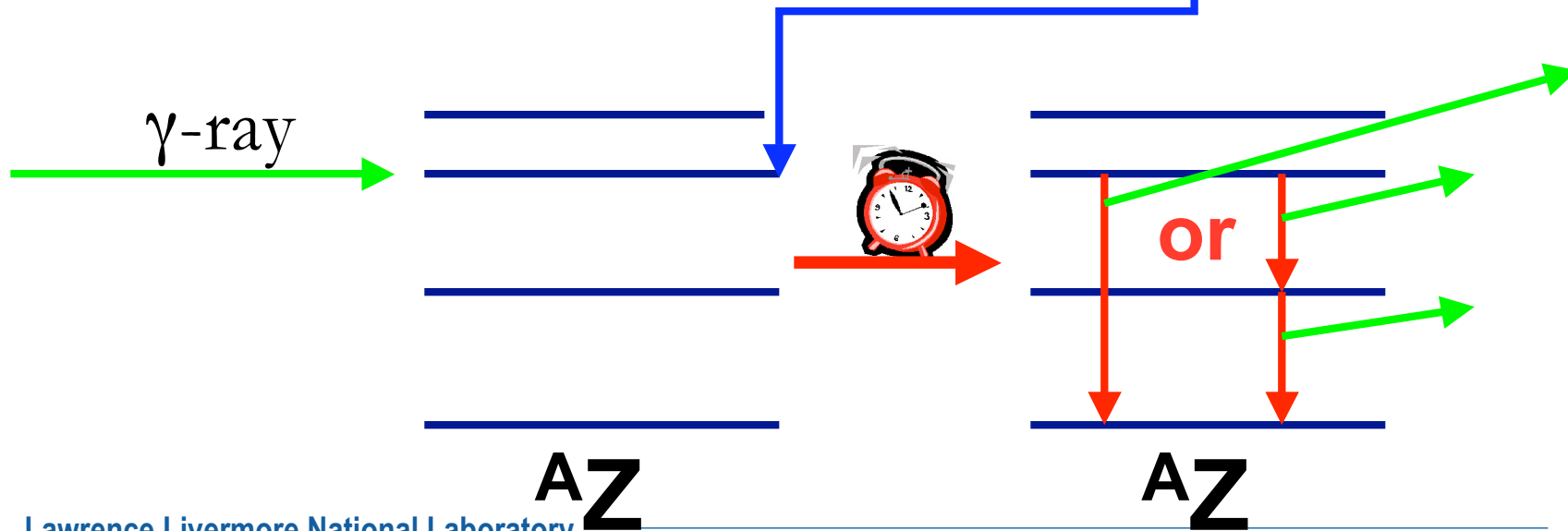
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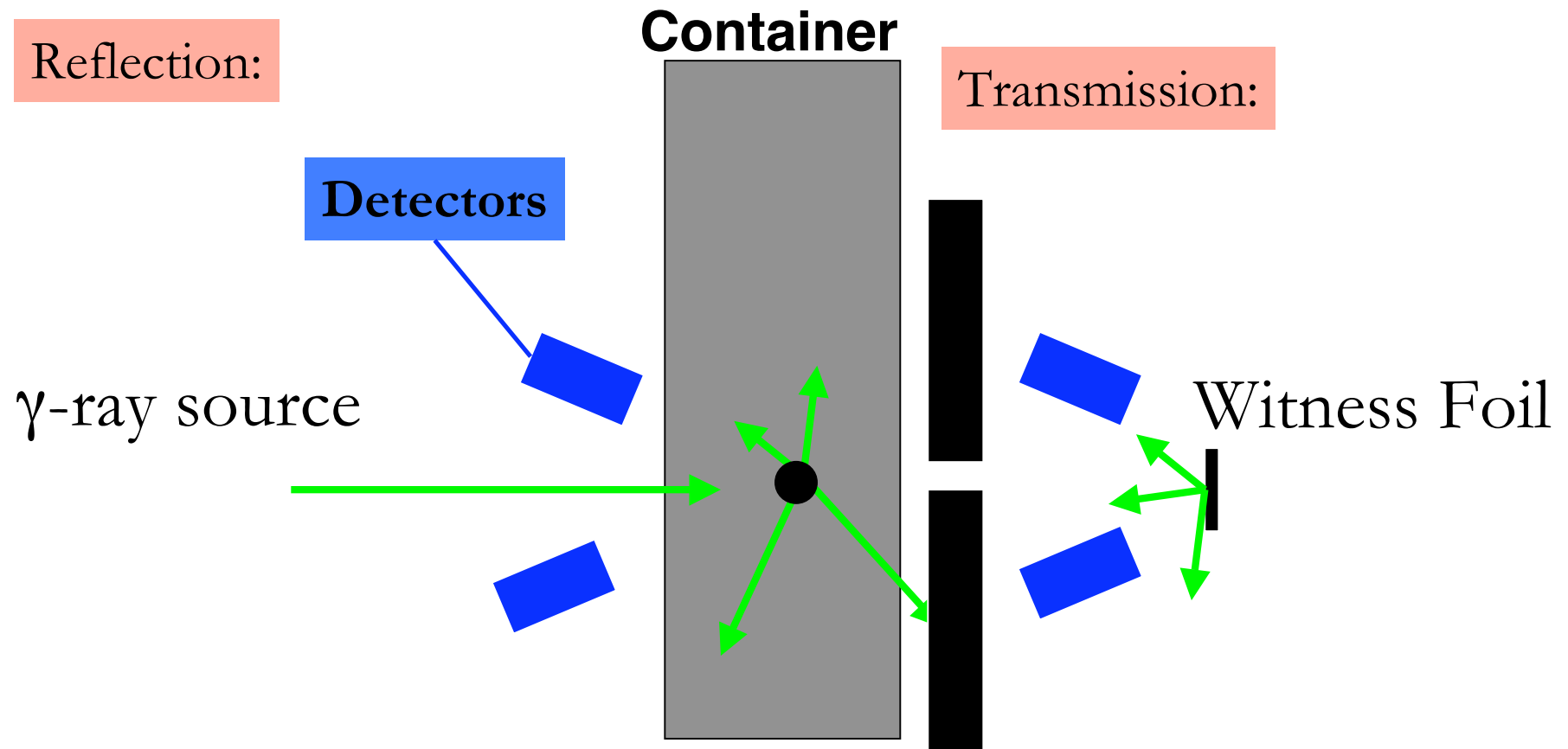
# Nuclear Resonance Fluorescence (NRF)

- An energetic photon ( $\gamma$ -ray) at a resonant energy of a particular isotope can excite that isotope.
- The excited nucleus then will decay by emitting a set of  $\gamma$ -rays
- Typically, dipole excitations (e.g. scissors mode)

**Level sensitive to  $\gamma$ -ray excitations**

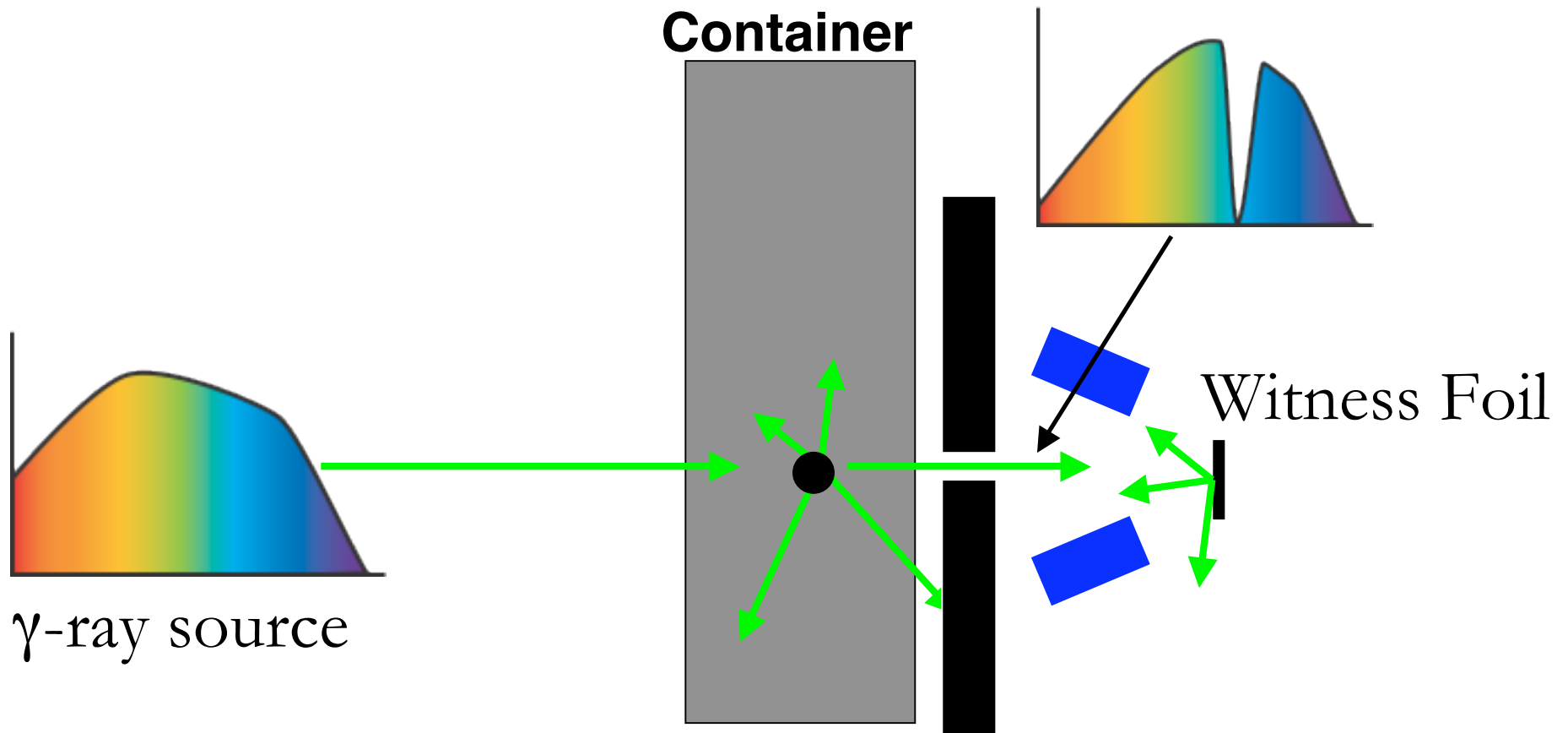


# Schematics of proposed NRF scan techniques



Transmission: scatter occurs in container **OR** from witness foil

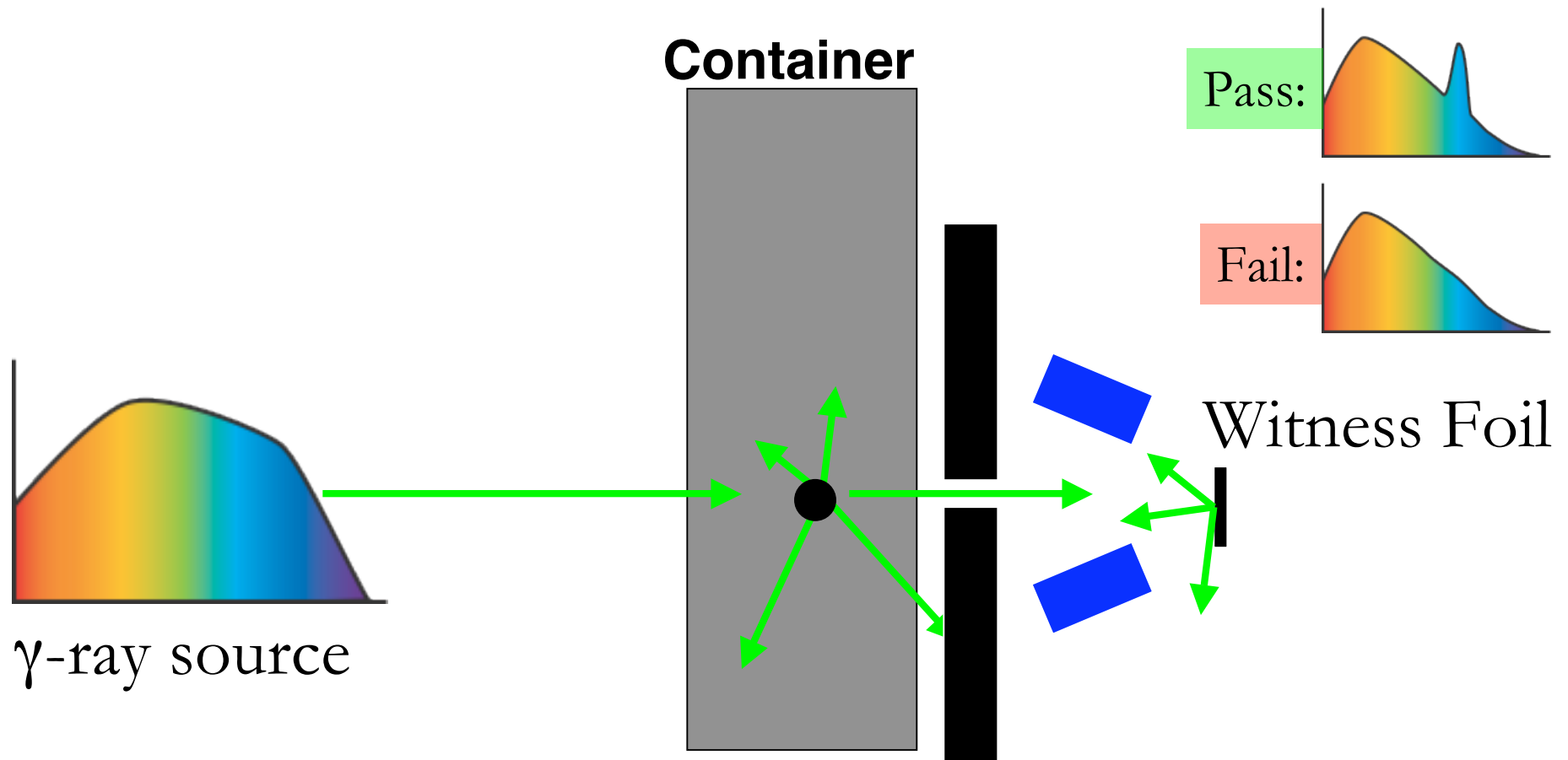
# Transmission technique



If material is present then the incident spectrum obtains a notch

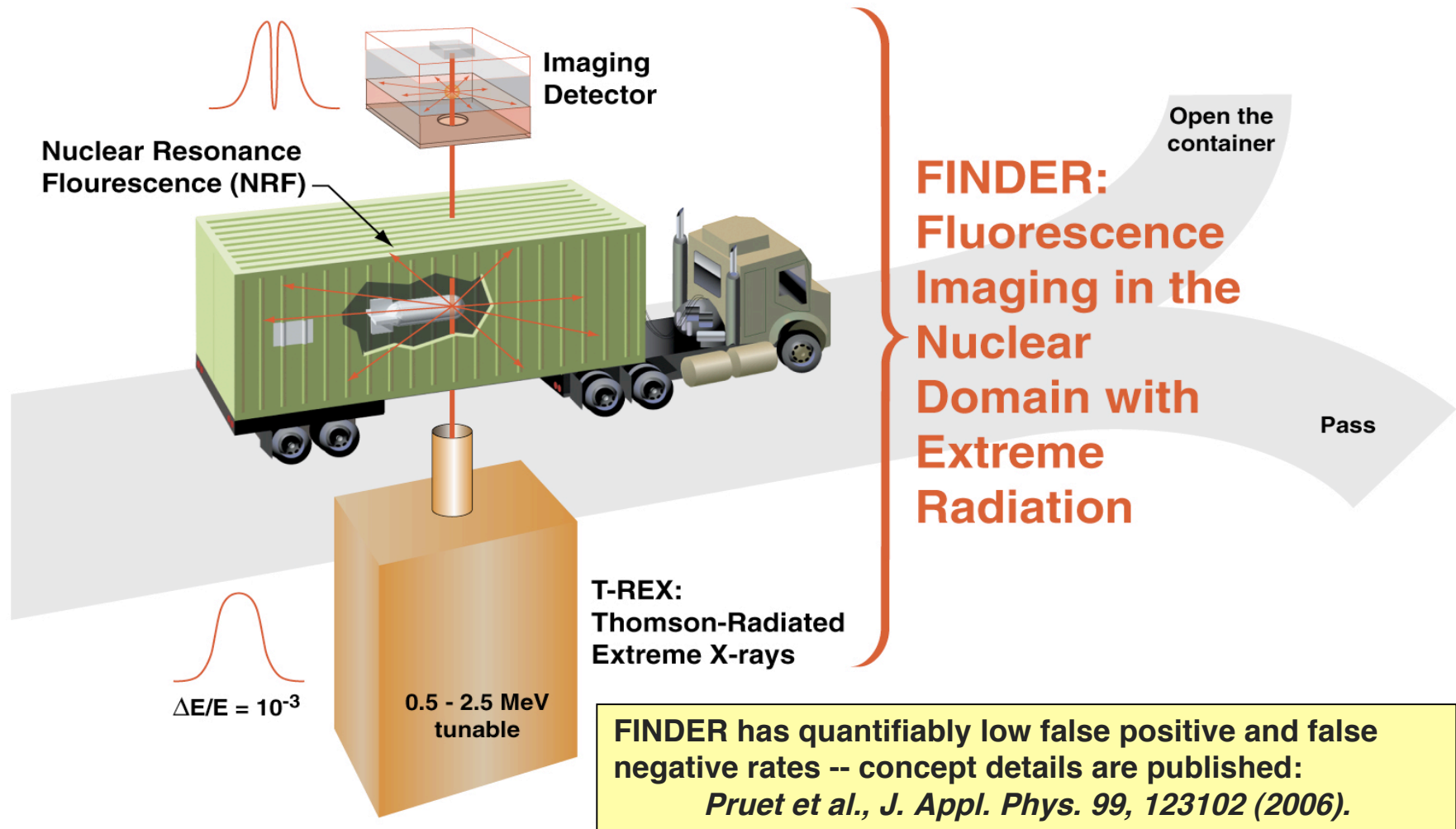


# Transmission technique

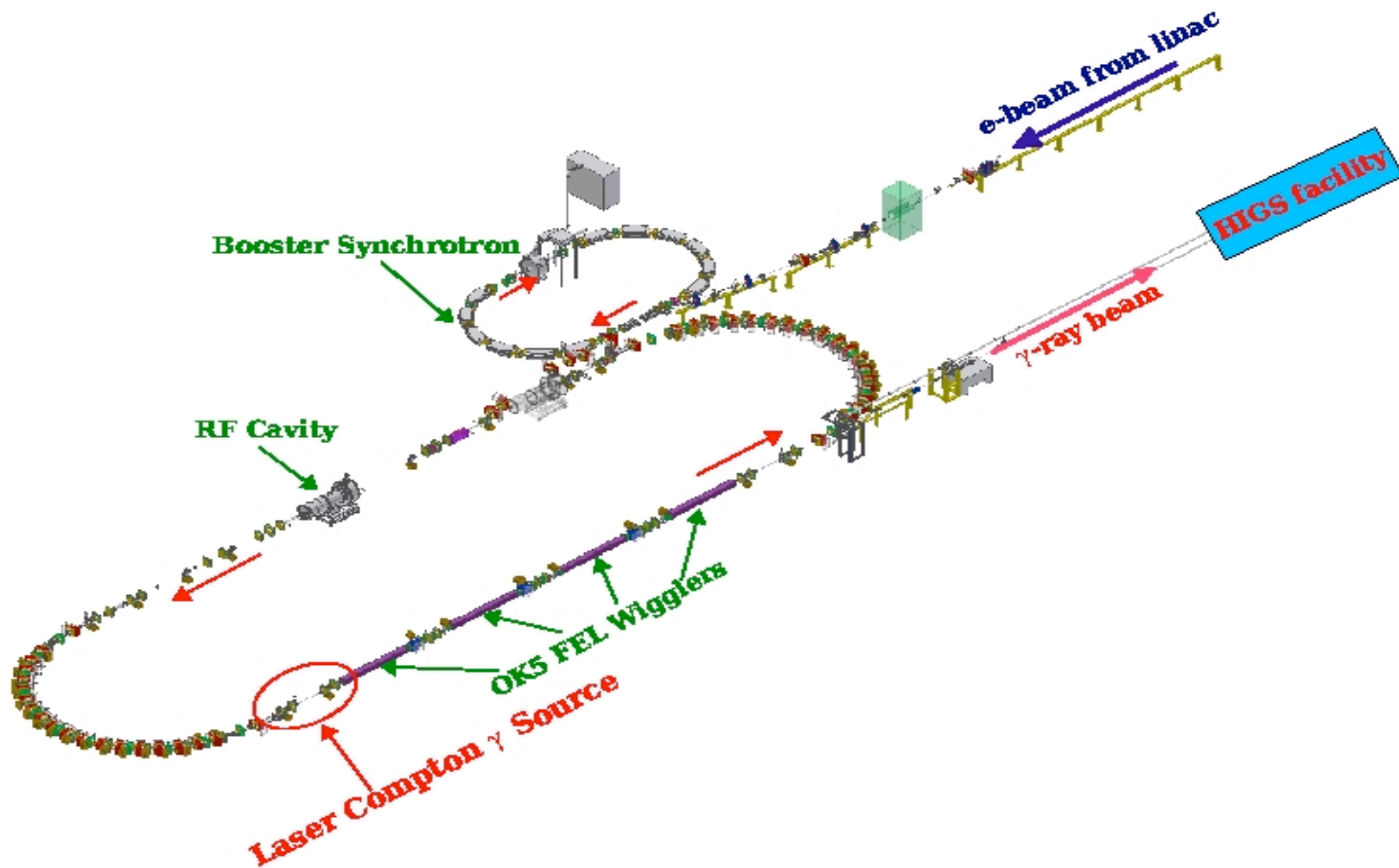


Scatter from witness foil exposes NRF lines **OR** not

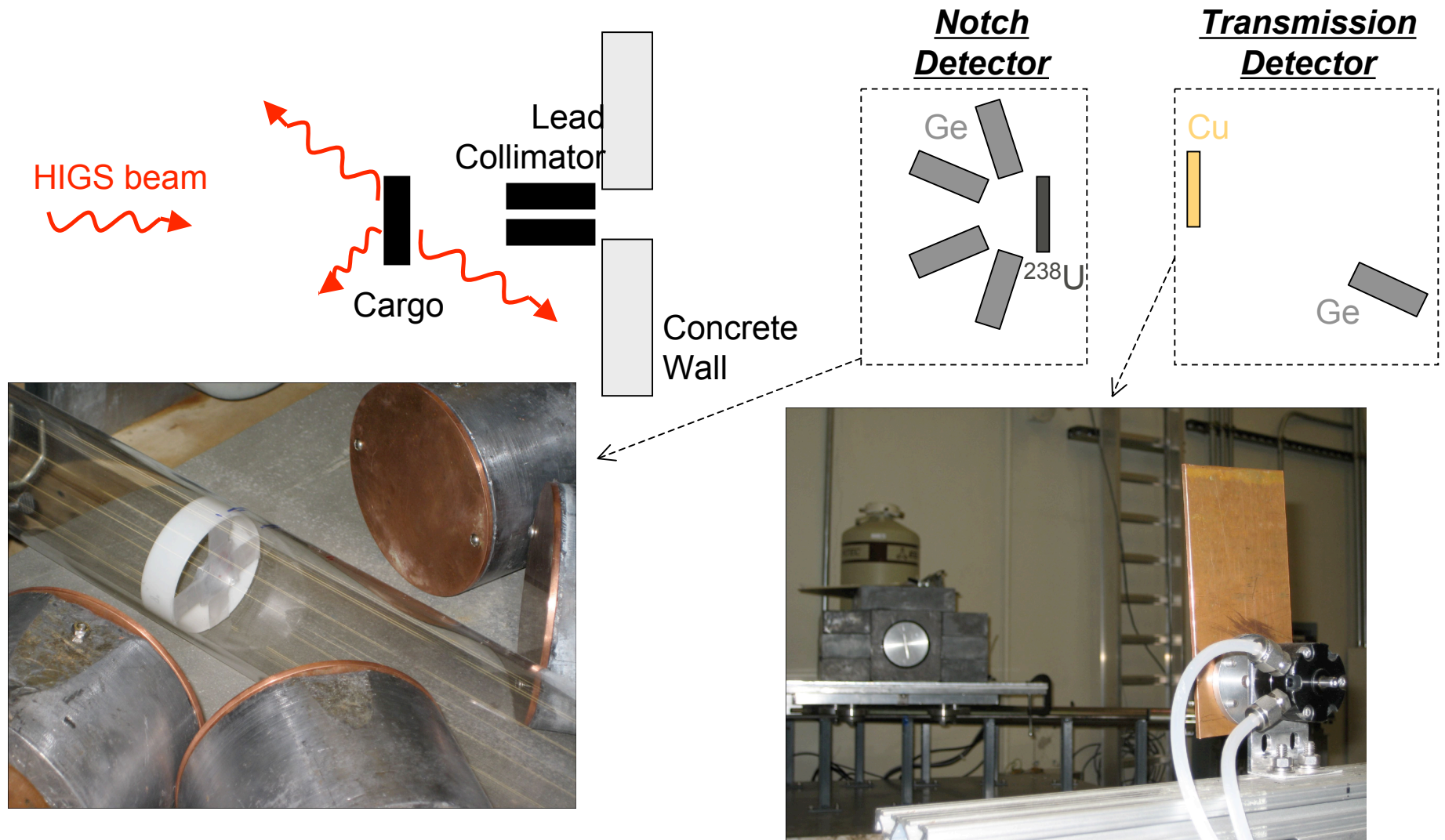
# LLNL concept: FINDER



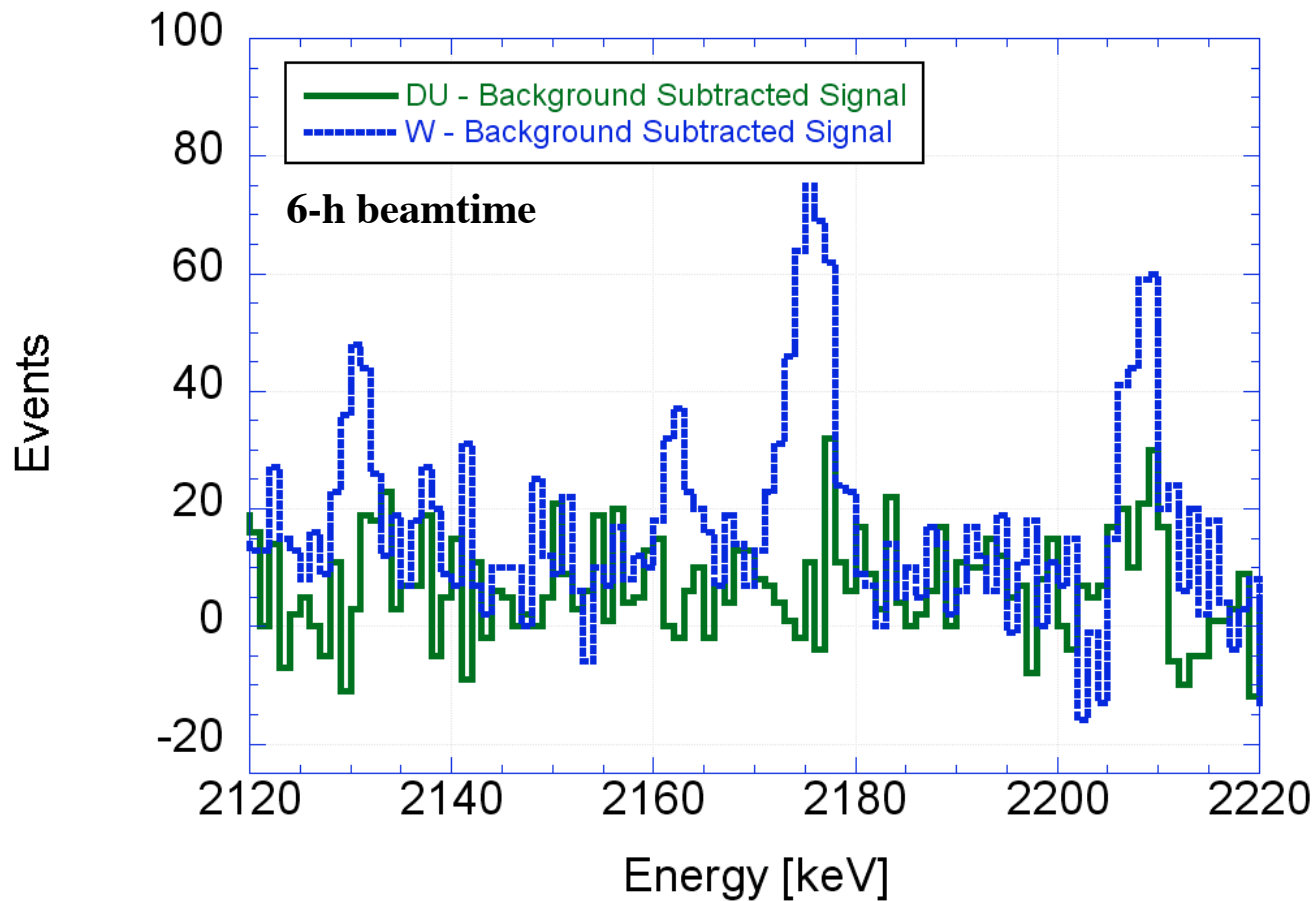
# HIgS



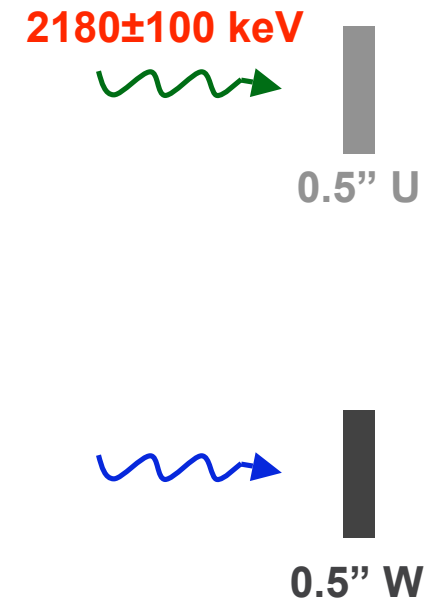
# Validation measurement for the transmission technique, Experimental setup at HIGS



# LLNL demonstrated transmission detection

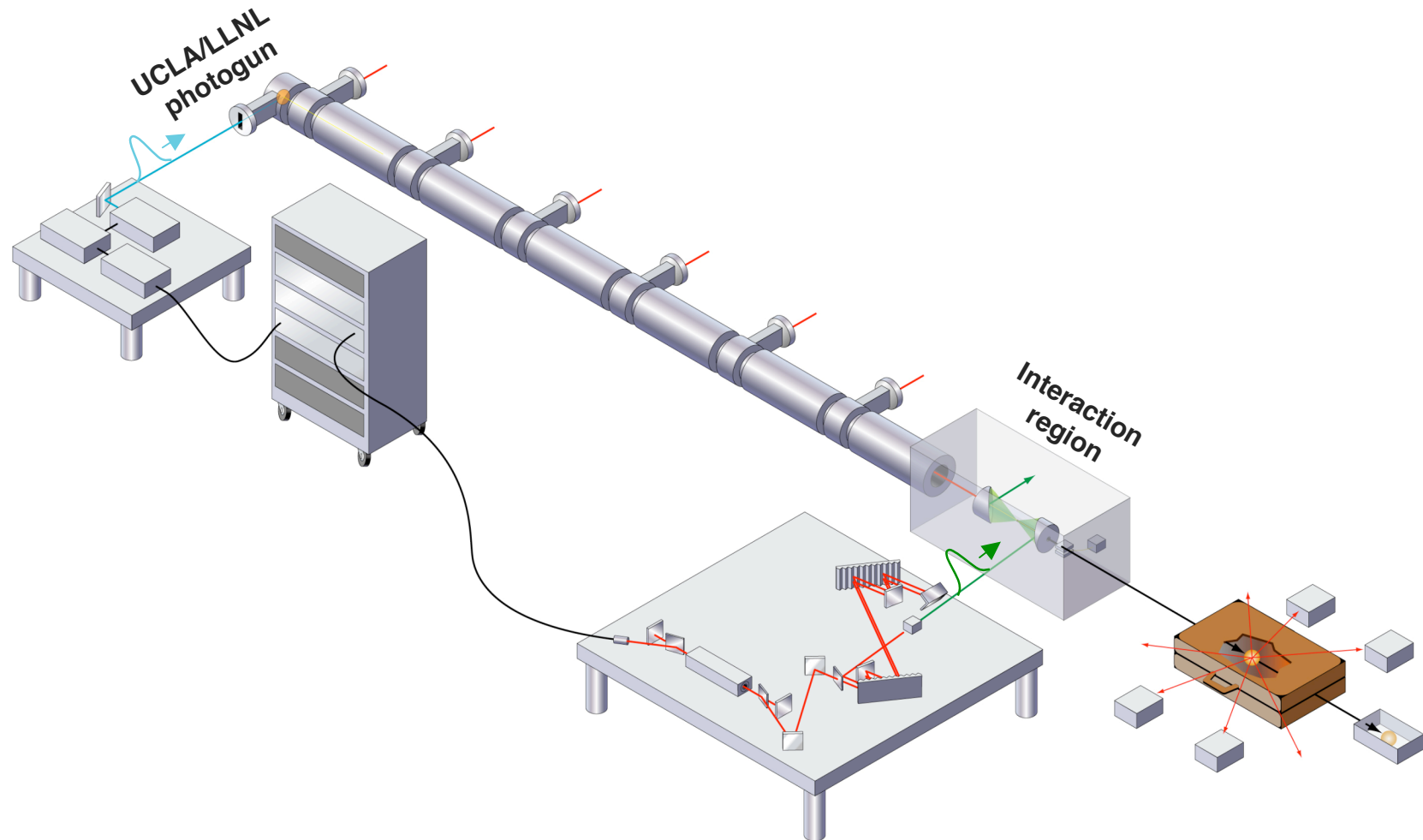


## Cargo scenarios

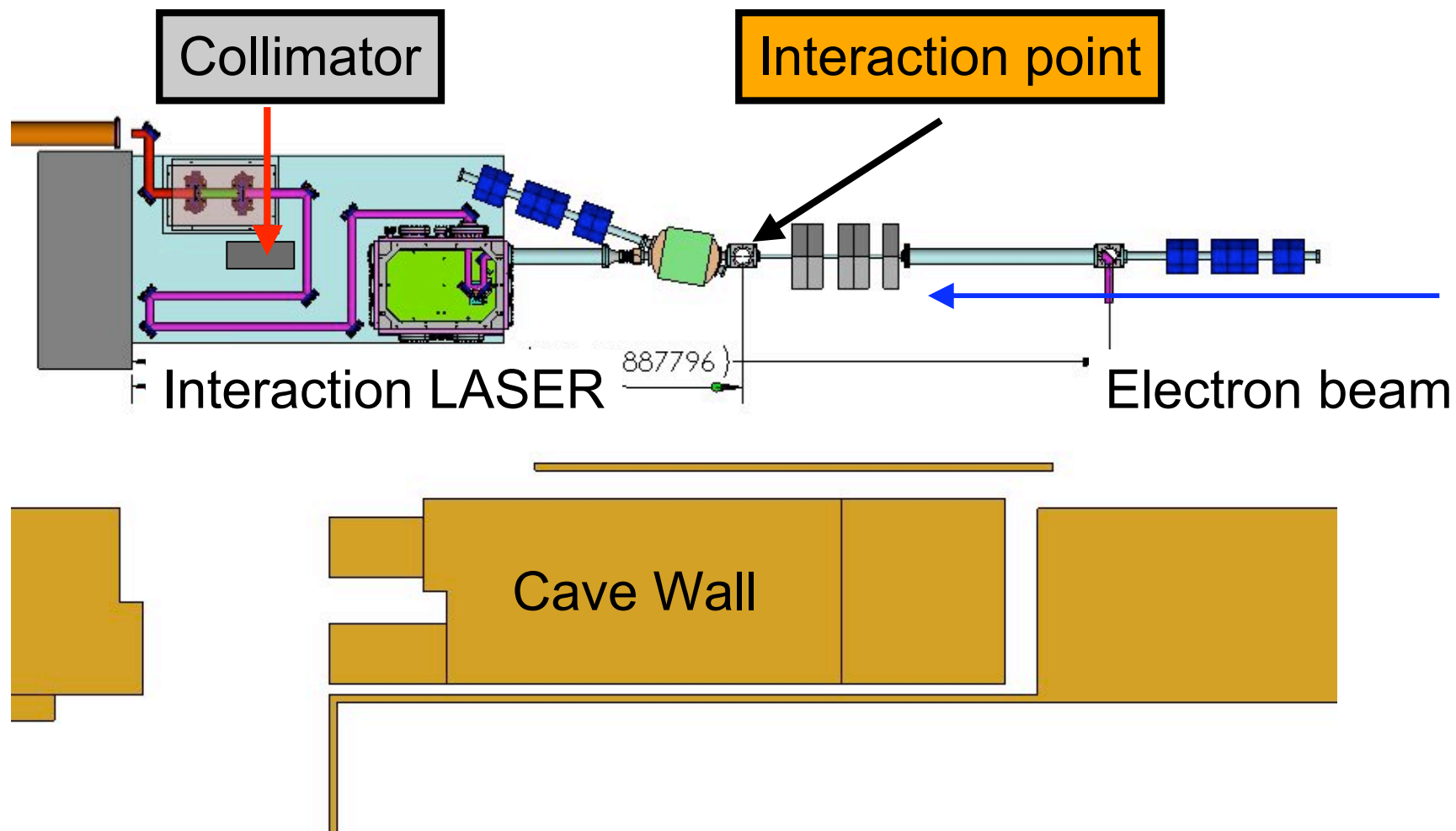


DU peaks imply the absence of DU in cargo

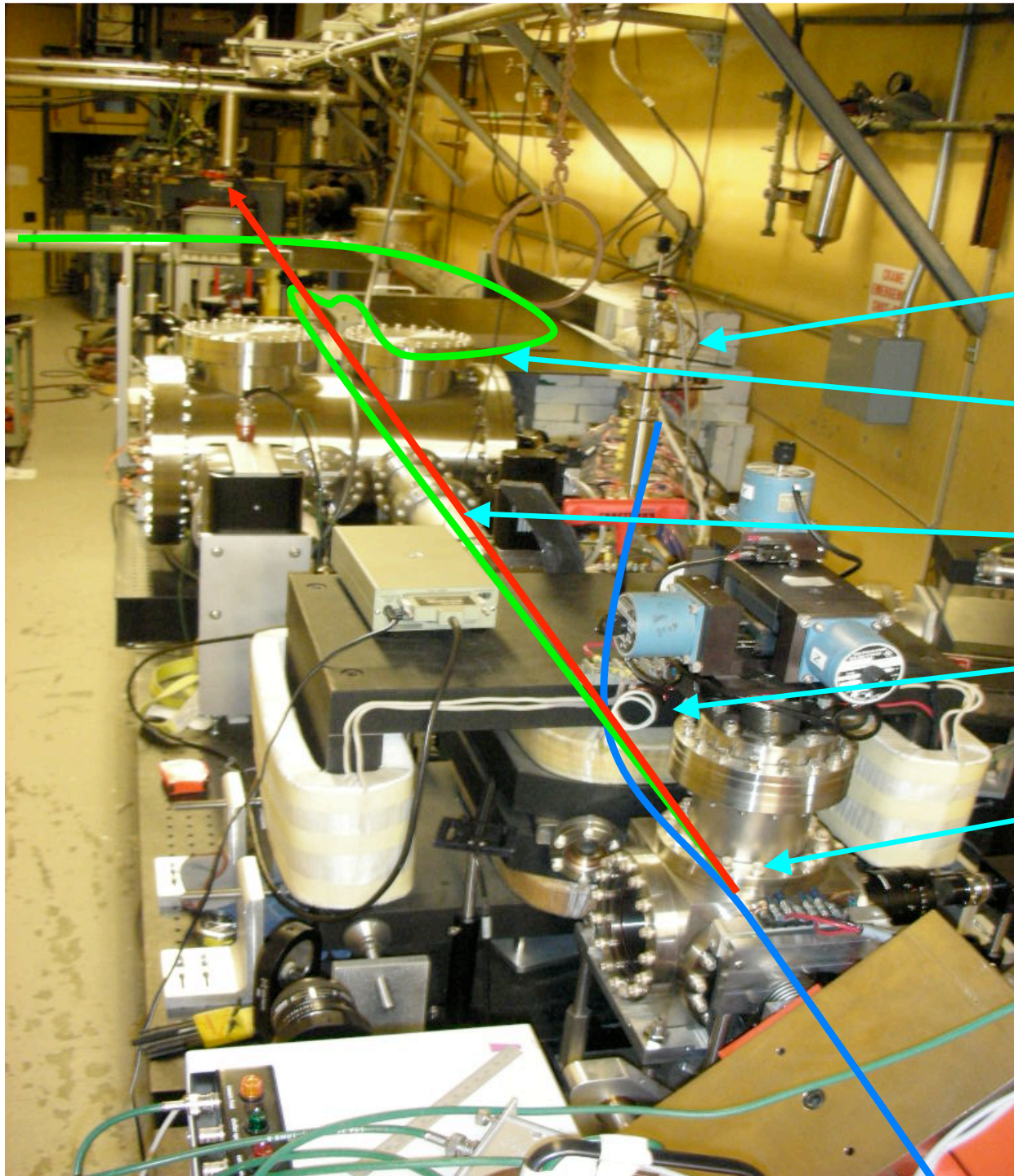
# T-REX schematic



# T-REX: Interaction layout







Electron beam dump

Laser

Photons

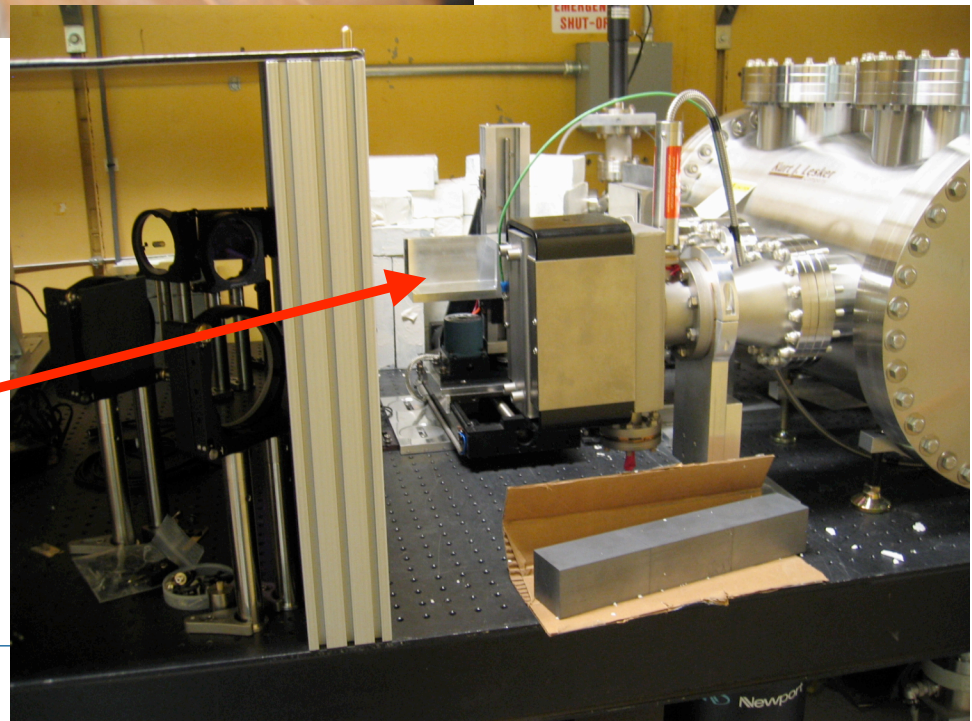
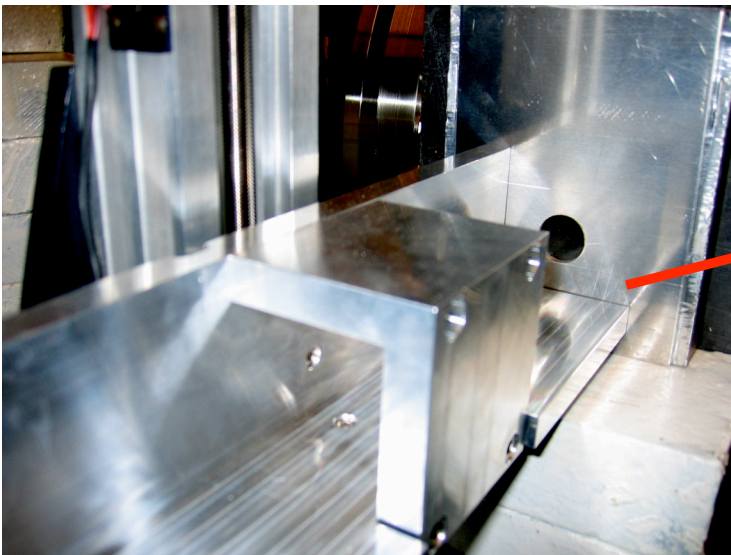
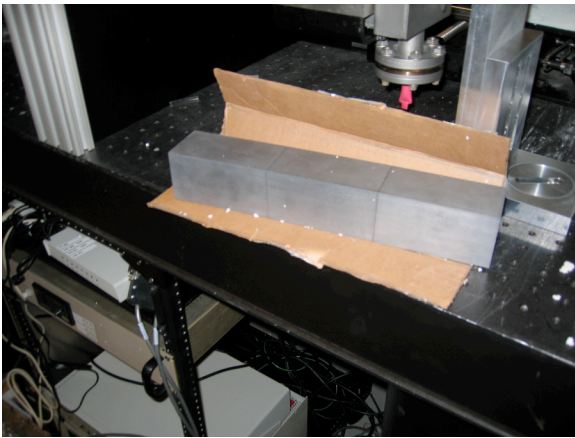
Dipole magnet

Interaction region

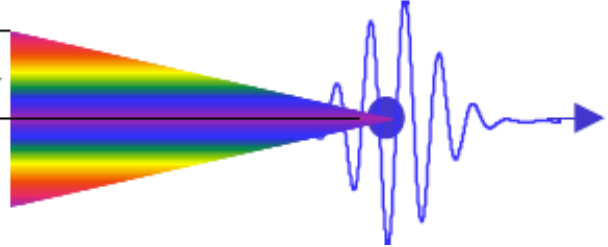




# Collimator



# T-REX photon production

$$\omega_s(\theta) = 4\gamma^2 \omega_{laser} \frac{1}{1 + \gamma^2 \theta^2} \quad \theta = 1 / \gamma$$


The diagram illustrates the T-REX photon production process. A relativistic electron beam, represented by a blue dot, interacts with a laser beam, represented by a rainbow-colored cone. The resulting x-ray beam is shown as a blue wavy line with an arrow pointing to the right, indicating the direction of propagation.

- Electron beam and laser beam are timed so that they reach the interaction point simultaneously
- Electron wiggles in the field of the photon and produces changing field of its own
- In the lab frame, this translates to energetically boosted, forward focused x-rays.
- Electron beam is 112 MeV, laser beam is 510 nm (2.4 eV)

⇒ **480 keV**

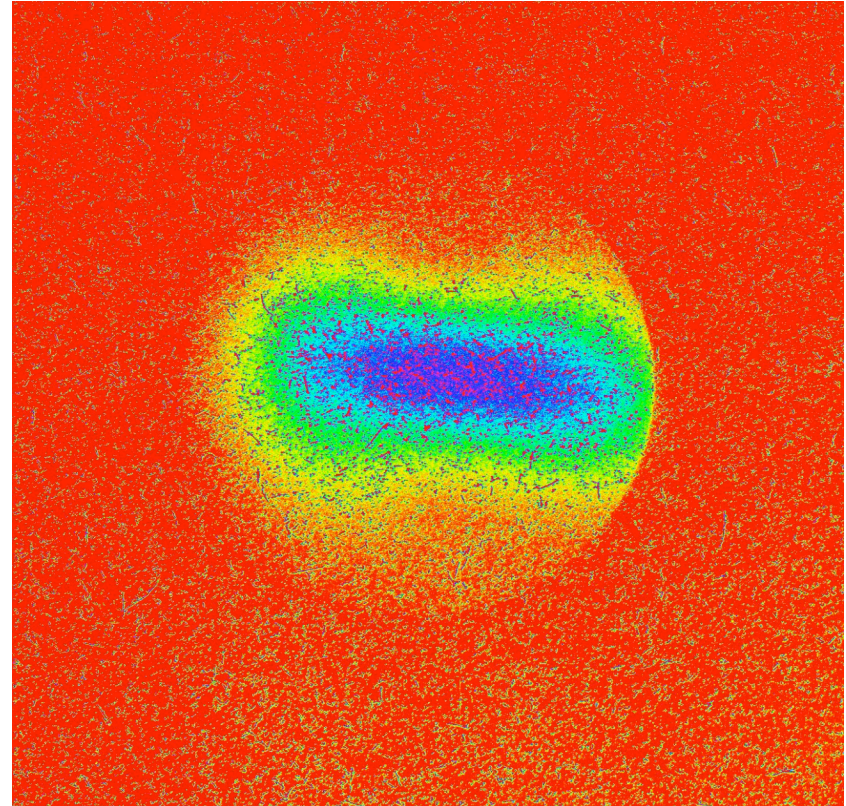
- **Necessary for demo on  $^7\text{Li}$**



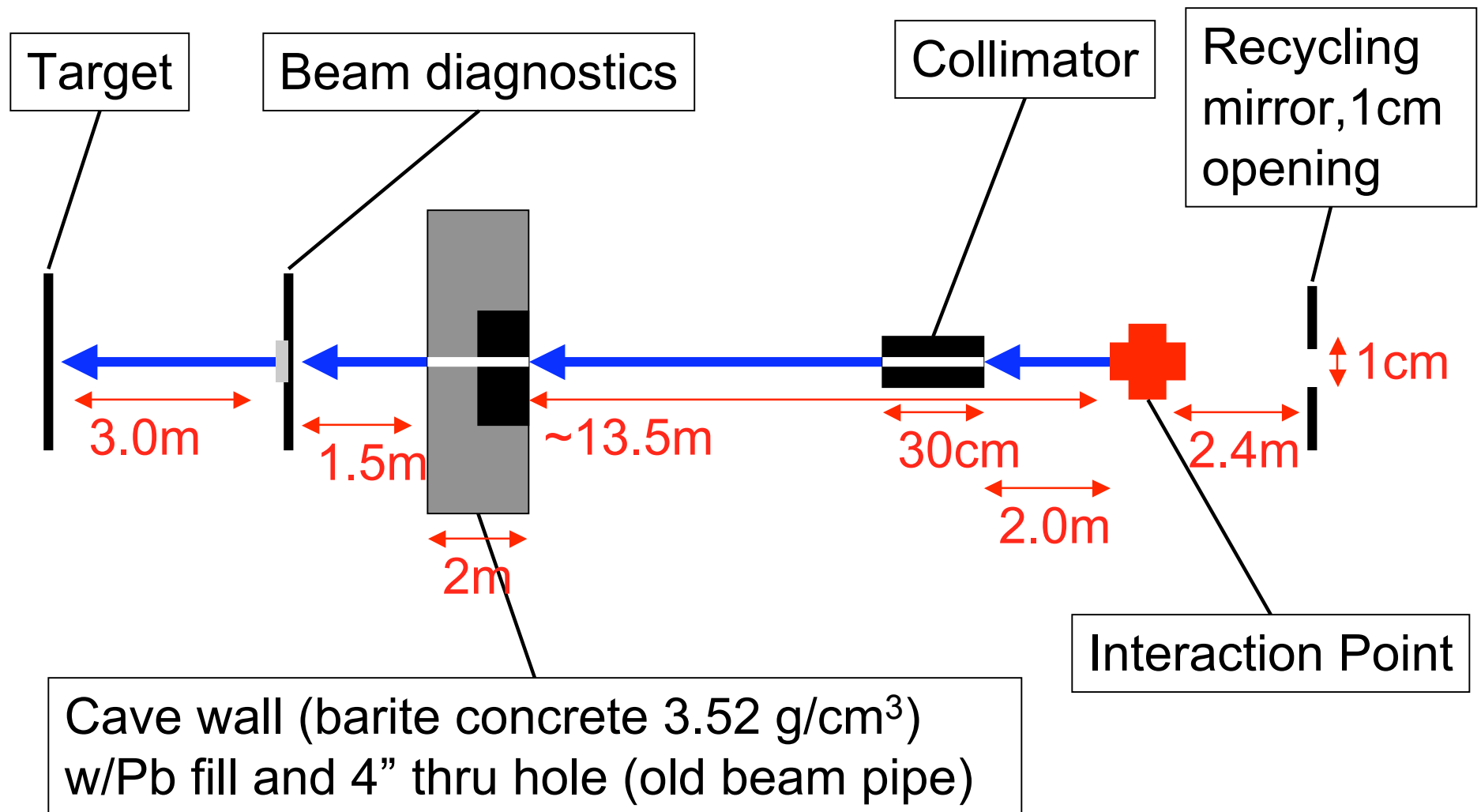
# T-REX First Light

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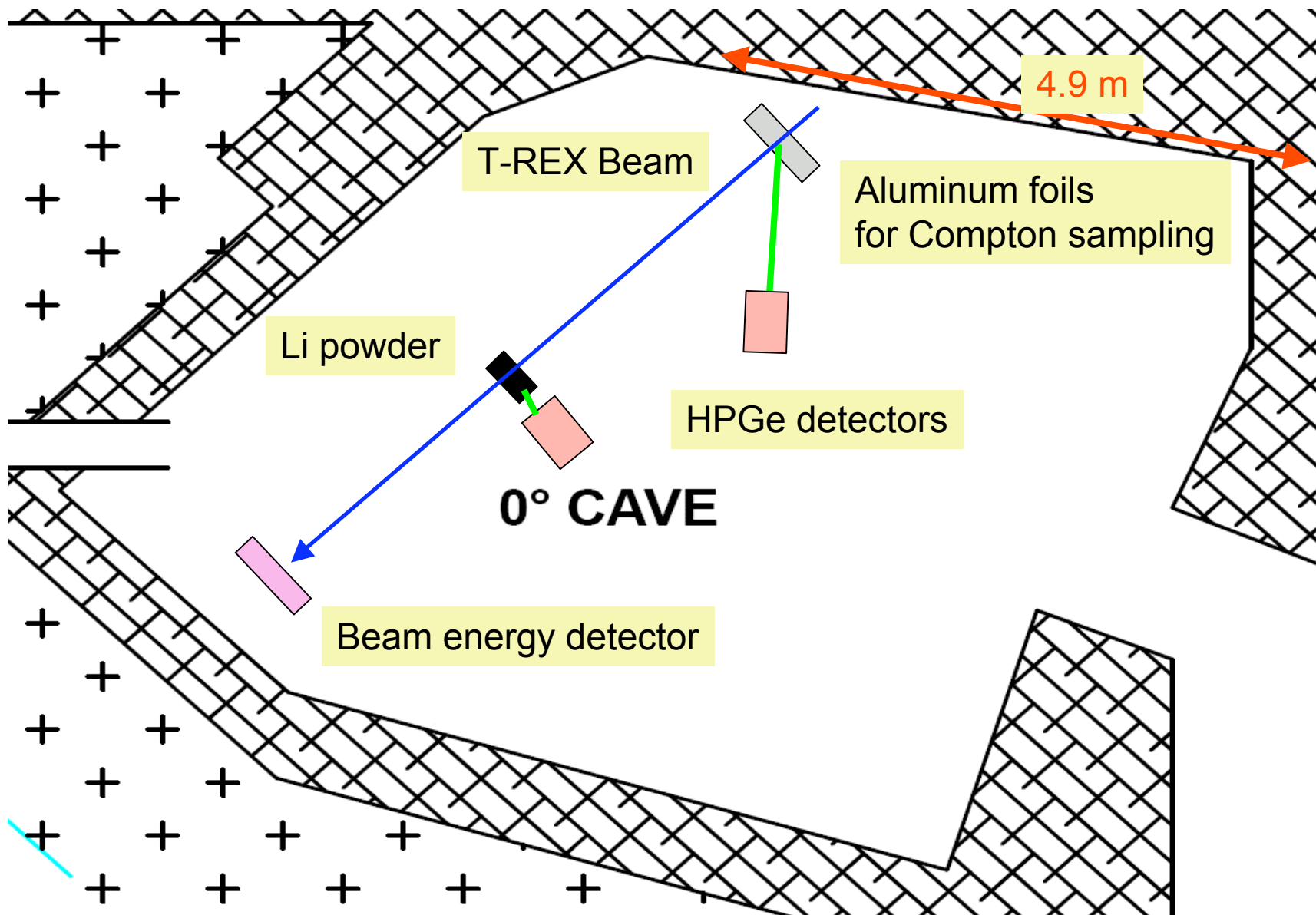
- Monday, Feb 25, 2008
- $1064 \text{ nm} + 120 \text{ MeV} = 260 \text{ keV}$ 
  - 1064 nm = infrared
- Picture: intensity image
- Circular feature is 1.75" diameter
- Field of view is 4" each side



# Flight-Path for demo



# FINDER demo layout







Al foil

HPGe detectors

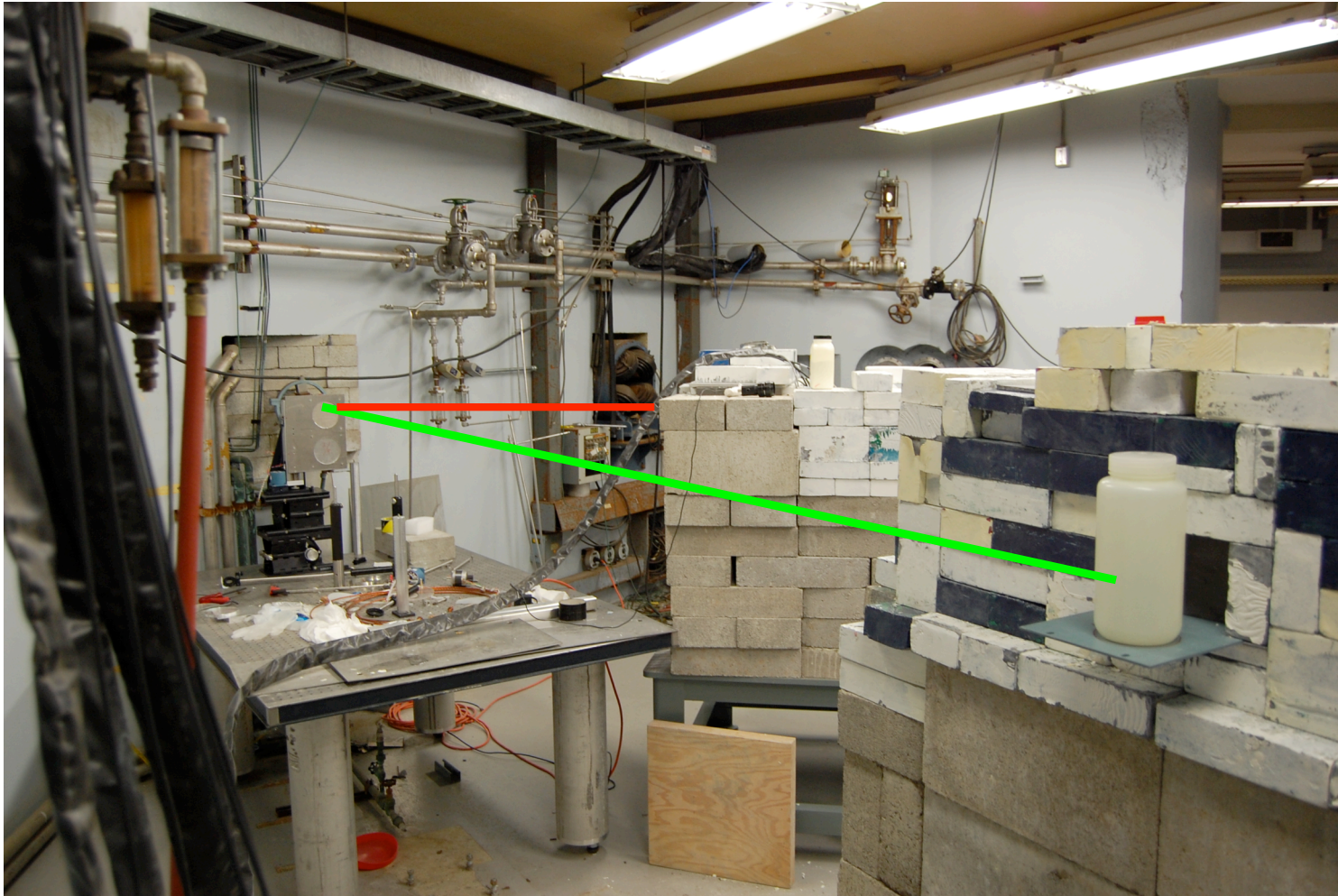
Li target

Beam monitor



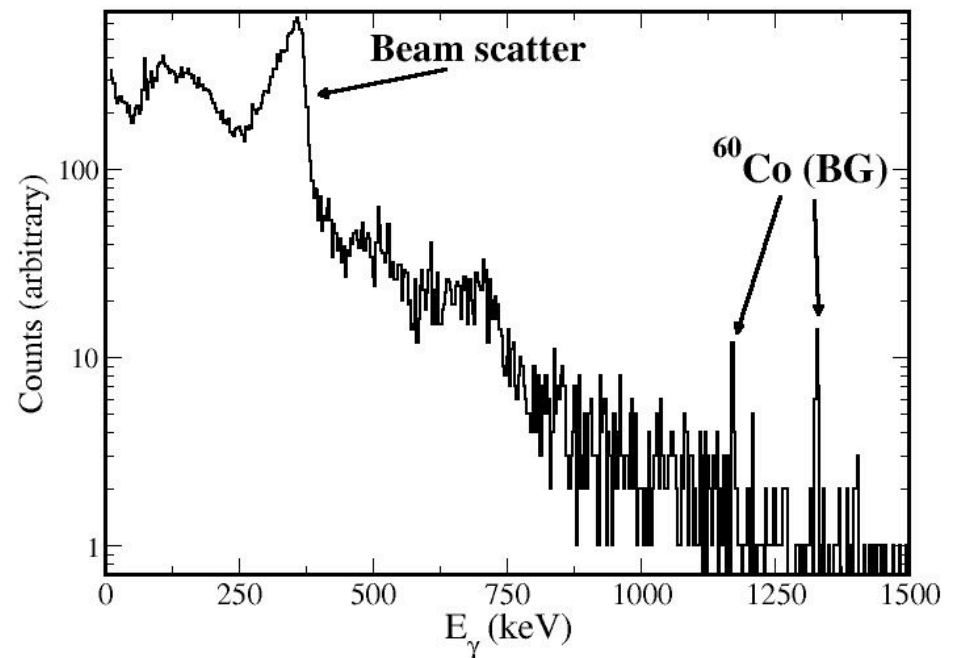


# LiH setup



# LiH demonstration

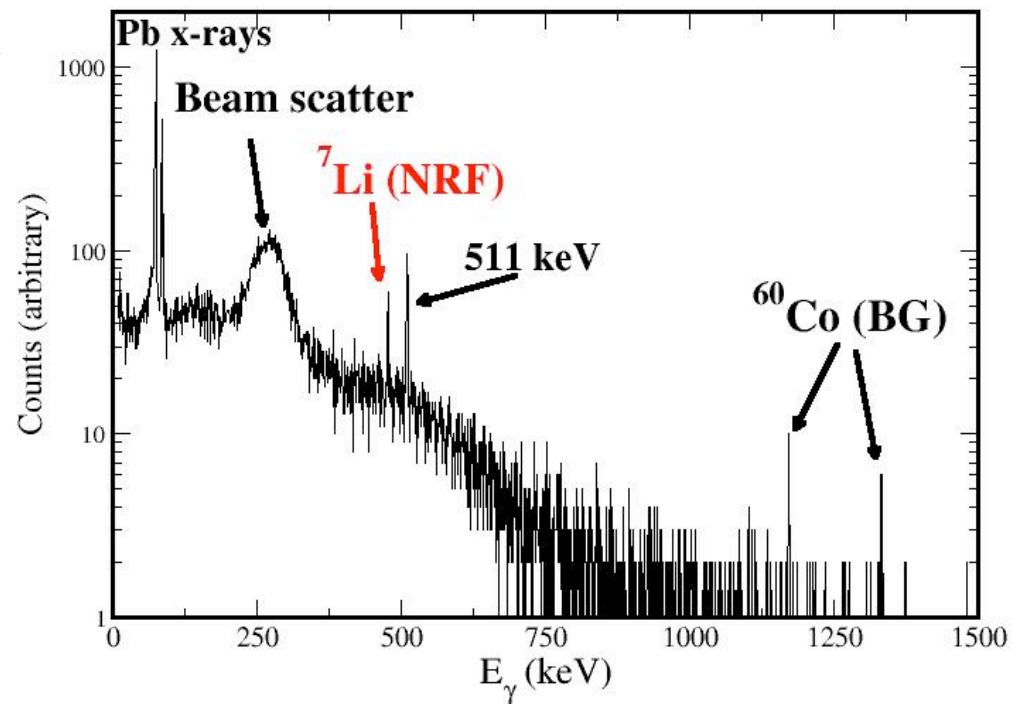
- Plot is spectrum taken from HPGe focused on Al plate.
- Detector is 48 degrees from beam axis
- 50% HPGe
- RF gated
- Beam is tuned to 480 keV





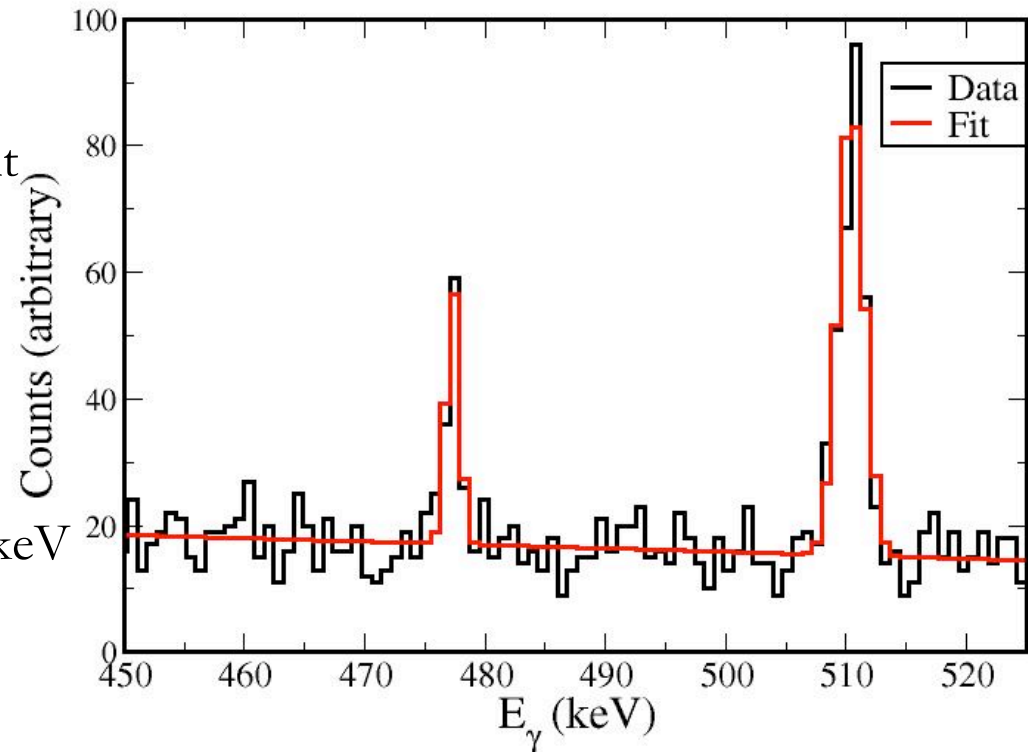
# LiH demonstration

- Plot is spectrum taken from HPGe focused on LiH target.
- Detector is 90 degrees from beam axis
- 50% HPGe
- RF gated
- Beam is tuned to 480 keV



# LiH demonstration

- Plot is spectrum taken from HPGe focused on LiH target.
- 511 keV is present
- 477 keV Li NRF peak is present
- Fit results
  - Chi-squared = 0.938
  - Sigma (477) = 6.727
  - Centroid = 477.63(19) keV
    - ENSDF = 477.612(3) keV
  - Width (477) = 2.43 keV
    - Consistent with calibration source



# Summary

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- NRF measurements have been performed on  $^{239}\text{Pu}$  2.5 MeV
  - Presentation at DNP
- Demonstration of notch detector was performed at HIGS
  - Used DU as a target material
  - Beam energy was 2.18 MeV (2% bandwidth)
  - NRF scatter from witness foil with no DU as “cargo”
  - No NRF scatter from witness foil with DU as “cargo”
- Demonstration of TREX source was performed
  - Beam tuned to Li
  - NRF state in Li at 477 keV was seen
  - On axis measurements of beam was overwhelmed by background

# Outlook

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- NRF measurements on other materials of interest to national security
  - Approved proposal
  - HIgS
- Demonstration of reflection versus transmission modes at HIgS
  - December measurements
- Need to better understand the sources of background for next generation gamma ray facilities



# Collaboration

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- M.S. Johnson, D.P. McNabb, C.A. Hagmann, *LLNL*
- TREX folks
- B194 operators

